

Original Research

Dual-Task Predictors in Graduate Healthcare Students with Athletic Backgrounds

Fernando Castillo, PT, DPT, PhD^{1a}, Brittani Freund, PT, DPT, ATC/L, PhD, SCS¹, Ryan Hulla, PhD², Janis Henricksen, PT, DPT, ScD, COMT, CEEAA¹, Neeraj Kumar, PT, DPT, PhD, NCS¹, Chad Schmeekle, PT, DPT, SCS¹, Shannon Estes, PT, DPT, NCS¹, Priya Karakkattil, PT, PhD, CBIS³

¹ Physical Therapy, University of St. Augustine for Health Sciences, ² Center for Research Design and Analysis, Texas Woman's University, ³ Physical Therapy, Texas Woman's University

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Background

Graduate healthcare students may have athletic backgrounds with history of concussion. Since these students spend much time multi-tasking while guarding, transferring, and treating patients in clinical settings, understanding the potential impact of external factors on dual-task abilities may help better equip them for success.

Purpose

The purpose of this study was to explore the relationship between concussion history, concussion education, and athletic history on academic performance and different single- and dual-task assessments among graduate healthcare students.

Study Design

A cross-sectional, repeated measures study.

Methods

A convenience sample of 33 graduate healthcare students, between the ages of 21-31 years old, were recruited from a health sciences institution. Inclusion criteria included enrollment at the institution and being between the ages of 18 and 35 years old. Exclusion criteria included a concussion within the past 30 days, current post-concussion symptoms, an upper and/or lower extremity injury, and/or pregnancy. Investigators collected subjective sport, concussion, and academic history before data collection. Then, participants were randomly assigned to perform single- and dual-task cognitive and walking activities. Parameters of gait and cognitive activity scores were measured to calculate dual-task cost (DTC). Next, principle component analyses were conducted to incorporate all measured variables into a single model for linear regression. Linear regressions were used to model the relationships between sport and concussion history and each component.

Results

Data were collected for 32 participants (aged 25 ± 2.46 years). A lack of concussion history was a significant predictor for experiencing greater DTC for performing a memory/recall task while walking backward. Additionally, lacking formal concussion education was a significant predictor for a higher DTC associated with the visuospatial

^a Dr. Fernando Castillo

Department of Physical Therapy, University of St. Augustine for Health Sciences, 901 W. Walnut Hill Lane, Suite 210A, Irving, TX 75038.

Email: fcastilldpt@gmail.com

Tel: 1-(870)-562-9484

task while walking backward. Finally, a longer history of athletic play predicted a lower undergraduate GPA.

Conclusions

Lacking concussion history and education as well as having a longer athletic history significantly predicted aspects of DTC and academic achievement in graduate healthcare students. These data may influence future decision-making criteria and processes when supporting and guiding students with athletic backgrounds through healthcare education programs involving psychomotor activities. Further studies with a larger sample and control for plausible confounding variables may provide additional insight.

Level of Evidence

2b

INTRODUCTION

Sport-related concussions (SRC) are classified by the Centers for Disease Control and Prevention (CDC) as mild traumatic brain injuries (mTBI).¹ According to the CDC, there is a one in five lifetime risk of SRC among adolescent athletes.¹ A recent questionnaire from an allied health science institution indicated that the majority of Doctor of Physical Therapy (DPT) students (82 out of 88) had a history of playing sports as adolescents (Appendix A). Doctor of Physical Therapy students, most of which may have been exposed to SRC, are expected to perform a variety of psychomotor tasks,² such as patient guarding and transferring, potentially inhibited by SRC.^{3,4} Prior to clinical work, students must successfully complete rigorous coursework. According to the Federation of State Boards of Physical Therapy, the percentage of passing National Physical Therapy Exam (NPTE) scores has decreased from 91% in 2020 to 86% in 2024.⁵ Although there are many factors that could impact academic performance in these students with athletic history, it is unclear if previous head injury is a significant contributor. Biochemical processes appearing as precursors to cognitive decline may develop inconspicuously following mTBI, such as SRC,¹ and persist chronically after resolution of symptomology.⁶ Persistent physiological dysfunction after previous SRC could negatively impact processing speed, knowledge acquisition, and general attention capabilities in DPT students. Consequently, investigating plausible correlations between history of SRC and parameters of gait as well as cognitive function may help guide facilitation of graduate students' success in doctoral programs. Over the past decade, many researchers have investigated sideline assessment methodologies, normative values, and return to play (RTP) and return to learn (RTL) protocols among adolescent and collegiate athletes with SRC^{6,7}; however, graduate healthcare students with potential history of concussion remain a relatively understudied population.

Dual-task cost (DTC), or the difference in performance outcomes between single- and dual-task activities,⁸ is a well documented component of concussion management. Dual-task cost has garnered increased attention because most sport and day-to-day activities involve some degree of multitasking with cognitive and motor tasks.⁹ In 2022, members of the International Conference on Concussion in Sport promoted a revised Sport Concussion Assessment

Tool-6 (SCAT6), which includes novel dual-task paradigms, for use during sideline evaluation following SRC.^{10,11} Inclusion of DTC paradigms in sideline assessment has improved tracking of non-subjective symptoms, such as gait deficits, that may not have been adequately assessed in the past.¹² Adolescent athletes with SRC demonstrate varying compensatory mechanisms during dual-task activities, leading to inconsistent comparison with normalized reference values.¹³ Similarly, assessments using electronic walkway systems have demonstrated that greater deficits (i.e., decreased velocity or increased base of support) exist under dual-task conditions.^{9,12,13} These findings have contributed to the continued refinement of RTP strategies, which have been widely accepted nationwide.¹⁰ However, given that most athletes experiencing SRC are also students, there is a continued need for more objective RTL programs.⁴

Research concerning student athletes' ability to return to classroom learning following concussion is limited. Research has focused mainly on adolescent and collegiate student athletes, despite the growing rates of concussion among non-pediatric, non-athlete populations.^{14,15} Most RTL methodologies have historically been rooted in recommendations based on independent opinions of school districts and healthcare teams.¹⁵ There has been inconsistent inclusion of pedagogical input¹⁶ and an overall lack of agreement regarding consistent guidelines for returning student athletes with SRC to the classroom.⁴ Importantly, the length of time an individual with concussion should dedicate toward a RTL program has not been fully established.¹⁷ This may be partly due to the high variation in number of days missed from school and severity of concussion for different populations.¹⁶ Establishing consistency between RTL protocols is also difficult. Disturbance to academic capability may remain evident despite resolution of most musculoskeletal and vestibular dysfunctions within a 28 day timeframe.^{16,17} In this case, subjects are said to be experiencing post-concussion syndrome (PCS), featuring a wide variety of symptoms including psychological issues, memory deficits, fine motor disturbances, migraines, headache, and neck pain, among others, potentially lasting months to even a year after initial injury.^{18,19} Despite these findings, literature exploring extended RTL concepts, including PCS, for populations of older students with history of SRC is virtually nonexistent. Therefore, it is possible that

potentially lingering effects of SRC on graduate healthcare students' academic potential may not be fully understood.

Finally, diagnosis of concussion itself is still being refined with inclusion of objective and validated measures in addition to subjective reporting. It is estimated that approximately 50% of the recorded 1.4 – 3.8 million concussions in the United States may go unreported.²⁰ This adds to the difficulty in fully understanding potentially lingering, transient effects of concussion after completing formal RTP protocols.^{3,7,20} Studies have reported that many student athletes with SRC continue to play while symptomatic without seeking medical attention and/or receiving appropriate education on reporting concussion.²¹ Such behaviors may contribute to persistence of long-term deficits outlasting resolution of more minor symptoms. These long-term deficits, such as poor attention and processing speed, were still found in a sample of 50-90-year-old participants with a history of mTBI in the last 30-40 years.⁶ Therefore, although most post-concussion symptoms typically return to baseline shortly after injury for younger athletes, there may be a continued need to assess older students with a history of SRC, especially those who may not have been adequately educated on reporting or symptomology. Given these foundational findings, the purpose of this study was to explore the relationship between concussion history, concussion education, and athletic history on academic performance and different single- and dual-task assessments among graduate healthcare students. The primary hypothesis was that concussion history would have the highest predictability of increased DTC and decreased academic performance.

METHODS

PARTICIPANTS

A convenience sample of 33 graduate healthcare students, between the ages of 21-31 years old, without concussion within the prior 30 days were recruited from a health sciences institution. The Institutional Review Board at the University of St. Augustine for Health Sciences approved the study. All participants provided written informed consent to participate in the study. Participants were included in the study if they were currently enrolled in the University of St. Augustine for Health Sciences College of Rehabilitative Sciences and were between the ages of 18-35 years old. Participants were excluded if they had a concussion in the past 30 days, were currently experiencing post-concussion symptoms, currently had an upper extremity injury, currently had a lower extremity injury, or were pregnant. Prior to commencing with data collection, participants completed a consent form as well as a questionnaire regarding demographic information and aspects of athletic history (i.e., years spent playing sports and whether they played a single or multiple sports) as well as concussion history (i.e., number of concussions, time since last concussion, and whether they've received proper concussion reporting and rehabilitation education).

PROTOCOL

All data collection was performed in a single laboratory room located in the participants' campus. Participants presented to the research stations in groups of three according to a sign-up sheet, scheduled around courses and investigator availability. After completing a consent and intake form, dominant leg length was measured from the anterior iliac spine to the medial malleolus. The leg length values were used to calculate normalized parameters of gait, accounting for variable morphology among participants. Then, each participant was randomly assigned to begin assessment at one of five stations, including three separate single-task cognitive activities (i.e., a single-task memory/recall, single-task visuospatial, and single-task Auditory Stroop Task (AST) station), a single-task gait session, and a dual-task cognitive and gait activity, each managed by a member of the research team (see Appendix B for a diagram). Participants progressed to the next station according to a randomized sequence.

Each single-task cognitive activity featured three different variations. Participants were randomly assigned to one of three variations for each of their single- and dual-task sessions. The three memory/recall variations included spelling words backwards, serial sevens, and reciting the months of the calendar year backwards. The three AST variations included identifying the pitch (i.e., high or low) of different words spoken by different male or female researchers. The three visuospatial task variations involved using a standard touchscreen mobile phone to type lists of animals, colors, or cities. Participants were instructed to complete three trials for each of the cognitive task stations using the same randomly assigned variation each time. The single-task gait activities were constituted by three trials of walking forward and three trials of walking backward on an electronic walkway. For the dual-task cognitive and gait station, students completed three trials of one memory/recall task variation, three trials of one AST variation, and three trials of one visuospatial task variation combined with forward and backward walking on an electronic walkway. Participants were allowed a practice trial before all single- and dual-task combinations and performed a total of 33 trials for the study.

ZENO™ WALKWAY GAIT ANALYSIS SYSTEM

The Zeno™ electronic walkway (© Zenometrics 2025, Peekskill, NY) using the Protokinetics Movement Analysis Software (PKMAS) was used to calculate normalized gait velocity (cm/s), step length (cm), stride length (cm), stride width (cm), stance time (% of gait cycle), swing time (% of gait cycle), gait pressure (DOP), cadence (steps/min), and the enhanced gait variability index (eGVI). In accordance with the protocol above, this walkway comprised two stations – a single-task walking forward and backward station and a dual-task walking forward and backward paired with a cognitive task station. Specifically, participants commenced and ceased walking at marked thresholds placed two feet from the start and end of the electronic walkway to account for acceleration and deceleration, respectively. For dual-

task assessment, the accompanying cognitive tasks began once students commenced walking (either forward or backward depending on random assignment of sessions) and ceased when students crossed the deceleration threshold beyond the end of the electronic walkway. The Zeno™ has been utilized in research to quantify the temporal and spatial parameters of gait in adolescents and adults aged 18-22 years.²² When the Zeno™ was compared to the force plate gold standard, reliability was excellent for all center of pressure measures in gait ($ICC_{2,k} \geq .96$).²² Strong validity has been established between the force plates and PKMAS at $r \geq .75$ for all outcome measurements.²² The walkway also has established moderate concurrent validity with the GAITrite® for spatial parameters of gait ($ICC_{(2,5)} = .72 - .92$) and temporal gait parameters ($ICC_{(2,5)} = .45 - .85$) during self-selected-paced walking.²³

MEMORY/RECALL TASKS

Participants completed the three trials of the following memory/recall task variations during single- or dual-task activities in a randomized manner: (1) serial subtraction by increments of seven (serial sevens),¹⁰ (2) spelling a five-letter word backward,²⁴ and (3) reciting the months of the calendar year backward.^{10,11,14} A methodological critique of dual-task assessments found serial sevens, reciting months of the year in reverse, and spelling common five letter words backwards to be the most commonly used cognitive tasks.²⁵ Specifically, serial sevens and reciting months of the year in reverse are both incorporated into the validated SCAT6.¹⁰ Spelling five letter words backwards is utilized in the Mental Status Examination,²⁴ a validated assessment of cognitive function.

AUDITORY STROOP TASK

The AST assesses verbal working memory, processing speed, and conflict-resolution function (i.e., distinguishing between a spoken word and the pitch of the spoken word itself), which may be commonly impaired following concussion.^{26,27} The assessment has been found to be a reliable adjunct for differentiating between individuals with and without concussion.^{25,28} Specifically, the AST has demonstrated high reliability (Cronbach's $\alpha = 0.94$, Intraclass Correlation (ICC) = 0.94; 95% Confidence Interval, 0.83-0.98) during dual-task gait assessment.²⁸ Pre-recorded words from three different voice variations were presented to participants during single- and dual-task trials. Participants were instructed to correctly identify whether the pitch of spoken words, regardless of the words themselves, were high or low. Each subsequent word was presented only after the participant responded with "high" or "low." Consistent with recently published procedures,²⁷ the spoken words, either in a high or low pitch (448 Hz and 187 Hz, respectively), were recorded using an external microphone at a sampling rate of 44100 Hz. Variations of the Stroop Task have been used during assessment of participants with history of concussion.^{25,26}

VISUOSPATIAL TASKS

Handheld devices have been used to assess cognitive function of adolescents with history of concussion.^{13,29,30} Specifically, the Brooks Spatial Memory Task has been commonly incorporated in single- and dual-task paradigms to assess the visuospatial component of cognition that may be impaired following concussion.³¹ It has been revealed that individuals with a history of concussion, on average six years prior to data collection, experienced significantly altered parameters of gait compared to controls while walking and performing the Brooks Spatial Memory Task.³¹ Additionally, adolescent athletes with acute SRC (symptoms lasting less than 28 days) and chronic SRC (symptoms lasting more than 28 days) have experienced significantly decreased velocity, step length, and single-limb support time compared to healthy reference values when walking while completing a visuospatial task.¹³ However, previous studies have elected to use a tablet device to establish novelty. In this present study, researchers incorporated a standard smartphone devoid of grammar and spellcheck capabilities to promote consistency with the type of device typically used by the population of interest. Participants were tasked with texting a consecutive list of items (i.e., animals, colors, or cities) during single- and dual-task sessions.

DUAL-TASK COST CALCULATION

Scores for all cognitive tasks (memory/recall, auditory, and visuospatial) were based on the percentage of correct attempts during each of the three trials in the single- and dual-task sessions. Then, the scores for all three trials were averaged together. For example, if during the single-task visuospatial session, a participant typed an average of nine words across three trials and correctly spelled an average of six, their score would be 66.67%. Dual-task cost between single- and dual-task trials for each cognitive activity during forward and backward gait was calculated as $((\frac{\text{Single Task Score} - \text{Dual Task Score}}{\text{Single Task Score}}) \times 100)$. The same equation was used to derive the DTC for each of the nine parameters of gait captured by the Zeno™ Electronic Walkway. This study collected 72 measurement variables which included measures of gait, cognition, and academic achievement (Appendix C).

STATISTICAL METHODS

PRINCIPAL COMPONENT ANALYSIS

To reduce the likelihood of Type I errors and to incorporate all variables into a single model for linear regression, principal component analyses were conducted on related variables. For example, the component score for velocity was derived from a principal component analysis of six velocity gait variables (velocity DTC during the three types of cognitive tasks while walking forward and backward). This procedure was applied to all variables of interest, reducing the total number of variables from 72 to 12 component scores (see Appendix C). Component scores were established based on the anticipated impact of a dual-task condi-

Table 1. Sample demographics.

Variable	N	Received Concussion Education	Did Not Receive Concussion Education
Sample (Male/Female)	32 (12/20)	12 (7/5)	20 (5/15)
Age, years (M $\pm$ SD)	25.00 $\pm$ 2.46	25.08 $\pm$ 2.81	24.95 $\pm$ 2.31
Contact Sports (N (%))	25 (78%)	11 (44%)	14 (56%)
Average Years in Sports	15.13 $\pm$ 5.10	17.83 $\pm$ 3.49	13.5 $\pm$ 4.365.30
Concussion History (N (%))	11 (34%)	9 (82%)	2 (18%)

tion (e.g., memory/recall task while walking forward) on the DTC for each of the nine parameters of gait as well as academic achievement parameters (grade point averages (GPA) and Graduate Record Examination (GRE) scores). Data distribution assumptions were met for 10 of the 12 component variables, with the two gait pressure variables (mean and ratio) not meeting appropriate skewness (-1 to 1) and kurtosis (-3 to 3) values.³² A log transformation was first applied to both pressure variables but was unable to bring the values within the appropriate range. A Box-Cox transformation was subsequently performed on the pressure variables, successfully normalizing their distribution within acceptable skewness and kurtosis values.

LINEAR REGRESSIONS

In addition to looking at the data as component scores, this study aimed to examine if concussion history, having formal concussion education while an athlete, and cumulative years of contact sport exposure could predict the six individual dual task component scores (cognitive tasks and gait parameters while walking forward and backward) and/or the five individual academic achievement measures (undergraduate science GPA, undergraduate program GPA, overall undergraduate GPA, GRE score, and current graduate program GPA). Log transformations were performed on memory/recall and auditory tests while walking backward to normalize skewness and kurtosis values. Data distribution assumptions were met for the remaining variables.

RESULTS

Thirty-three students voluntarily participated in this study. After the initial intake, one participant withdrew due to an upper extremity injury unrelated to the study. Therefore, subsequent data analysis was completed for 32 participants (aged 25 ± 2.46 years). Thirty four percent reported a history of concussion ($n = 11$). However, 62.5% of the participants reported they never received education on concussions nor concussion reporting ($n = 20$). Ninety-seven percent of the participants had a history of playing sports ($n = 31$); 81% reported playing contact sports for an average of 9.16 years ($n = 25$); and 19% reported participating in non-contact sports for an average of 14.83 years ($n = 6$). Only one participant identified as a non-athlete. [Table 1](#) reflects sample demographic for the initial intake.

CONCUSSION HISTORY EFFECTS

To investigate whether concussion history could predict the scores of the 12 parameters of gait and academic achievement measures, 12 linear regressions were performed. Concussion history was a significant predictor of the DTC component score ($F(1, 30) = 4.53$, $p = 0.042$, $R^2 = .13$), accounting for 13% of the variance (cognitive tasks while walking forward and backward). The results indicated that individuals with no concussion history were predicted to experience increased DTC when performing dual tasks ($B = 0.75$, $p = 0.042$). Concussion history did not significantly predict any other variable component scores ($p > 0.05$) ([Table 2](#)).

To further examine which specific DTC measures (memory/recall, auditory, and visuospatial tasks while walking forward and backward) could be predicted by concussion history, six linear regressions were conducted. The results indicated that concussion history was a significant predictor for the DTC of performing the memory/recall task while walking backward ($F(1,30) = 5.20$, $p = 0.030$, $R^2 = .15$), accounting for 15% of the variance. Individuals with no concussion history were predicted to experience an increased DTC when performing the memory/recall task while walking backward ($B = 0.06$, $p = 0.030$). No other DTC measures were significantly predicted by concussion history ($p > 0.05$) ([Table 3](#)).

CONCUSSION EDUCATION EFFECTS

Upon further review of descriptive statistics of each group, results revealed 76% ($n = 16$) of the non-concussion history group ($n = 21$) had never received education on concussion nor education on how to report a concussion, whereas 82% ($n = 9$) of those with a history of concussion were educated on concussion reporting. To investigate whether having a history of concussion education could predict the scores of the 12 spatiotemporal parameters of gait and academic achievement measures, 12 linear regressions were performed. Among these variables, concussion education was a significant predictor of the DTC component score ($F(1,30) = 4.48$, $p = 0.043$, $R^2 = .13$), accounting for 13% of the variance. The results indicated that individuals with no history of concussion education were predicted to have increased DTC when performing dual tasks ($B = 0.73$, $p = 0.043$). Concussion education did not significantly predict any other variable component scores ([Table 4](#)).

To further examine which specific DTC measures could be predicted by a history of concussion education, six linear

Table 2. Concussion history predicting variables of interest components scores results.

Component Scores	F	R ²	B ^a	SE	p-value
Dual Task	4.53	.13	0.75	0.35	0.042*
Velocity	0.12	.00	-0.13	0.38	0.731
Step Length	0.30	.01	-0.20	0.38	0.591
Stride Length	0.30	.01	-0.21	0.38	0.598
Stride Width	0.25	.01	-0.19	0.38	0.619
Stance Width	1.31	.04	0.42	0.37	0.261
Swing	1.82	.06	-0.50	0.37	0.187
Mean DOP	1.13	.04	-0.37	0.34	0.297
DOP Ratio	0.01	.00	-0.04	0.36	0.907
Cadence	0.00	.00	0.02	0.38	0.960
eGVI	0.01	.00	-0.04	0.38	0.916
Academic Achievement	0.00	.00	-0.02	0.39	0.956

Abbreviations: DOP, gait pressure; eGVI, average enhanced gait variability index. ^a Concussion history was coded as 1 indicates concussion history; 2 indicates no concussion history. A positive *B* value indicates no history of concussion is related to a higher score). *Denotes a component significantly predicted by a history of concussion.

Table 3. Concussion history predicting dual-task cost results.

Dual-Task Component Variables	F	R ²	B	SE	p-value
Memory/Recall + WF	1.99	.06	-18.47	13.09	0.169
Auditory Stroop + WF	0.05	.00	-0.51	2.26	0.823
Visuospatial Task + WF	0.01	.00	-0.92	9.44	0.923
Memory/Recall + WB	5.20	.15	0.06	0.03	0.030*
Auditory Stroop + WB	2.89	.09	-0.05	0.03	0.100
Visuospatial Task +WB	1.45	.05	9.55	7.94	0.239

Abbreviations: WF, walking forward; WB, walking backward. *Denotes a dual-task cost component significantly predicted by a history of concussion.

Table 4. Concussion education predicting variables of interest components scores results.

Component Scores	F	R ²	B ^a	SE	p-value
Dual Task	4.48	.13	0.73	0.35	0.043*
Velocity	0.13	.00	-0.13	0.37	0.720
Step Length	0.70	.02	-0.31	0.37	0.410
Stride Length	0.76	.03	-0.32	0.37	0.391
Stride Width	2.12	.07	0.52	0.36	0.155
Stance Width	0.52	.02	0.27	0.37	0.477
Swing	0.70	.02	-0.31	0.37	0.412
Mean DOP	0.02	.00	-0.05	0.35	0.889
DOP Ratio	0.12	.00	0.12	0.35	0.733
Cadence	0.07	.00	0.10	0.37	0.790
eGVI	0.25	.01	-0.18	0.37	0.623
Academic Achievement	1.43	.05	0.44	0.37	0.242

Abbreviations: DOP, gait pressure; eGVI, average enhanced gait variability index. ^a Concussion education was coded as 1 indicates having education about concussions; 2 indicates having no concussion education. A positive *B* value indicates no concussion education is related to a higher cost. *Denotes a component significantly predicted by having no concussion education.

regressions were conducted. The results indicated that concussion education was a significant predictor for the DTC of performing the texting task while walking backward ($F(1,30) = 4.46$, $p = 0.043$, $R^2 = .13$), accounting for 13% of the variance. Specifically, individuals with no concussion

education were predicted to experience increased DTC when performing the texting task while walking backward ($B = 15.71$, $p = 0.043$). All other DTC measures were not significantly predicted by a history of concussion education ($p > 0.05$) (Table 5).

Table 5. Concussion education predicting dual-task cost results.

Dual-Task Component Variables	F	R ²	B	SE	p-value
Memory/Recall + WF	0.71	.02	-11.04	13.12	0.406
Auditory Stroop + WF	0.15	.01	-0.87	2.21	0.697
Visuospatial Task + WF	1.23	.04	10.27	9.07	0.266
Memory/Recall + WB	1.67	.05	-2.45	0.05	0.206
Auditory Stroop + WB	0.42	.01	-0.02	0.03	0.521
Visuospatial Task +WB	4.46	.13	15.71	7.44	0.043*

Abbreviations: WF, walking forward; WB, walking backward. *Denotes a dual-task cost component significantly predicted by having no concussion education.

Table 6. Years played contact sports predicting variables of interest component scores results.

Component Scores	F	R ²	B ^a	SE	p-value
Dual Task	1.17	.05	-0.04	0.03	0.269
Velocity	0.61	.03	0.03	0.04	0.441
Step Length	1.33	.06	0.05	0.04	0.261
Stride Length	1.49	.06	0.05	0.04	0.234
Stride Width	3.40	.13	-0.64	0.04	0.078
Stance Width	0.40	.02	-0.03	0.04	0.535
Swing	0.32	.01	0.23	0.04	0.578
Mean DOP	0.04	.00	0.01	0.03	0.838
DOP Ratio	0.01	.00	0.00	0.03	0.919
Cadence	0.05	.00	0.01	0.04	0.823
eGVI	0.03	.00	-0.01	0.04	0.867
Academic Achievement	5.05	.19	-0.08	0.34	0.035*

Abbreviations: DOP, gait pressure; eGVI, average enhanced gait variability index.^a A negative *B* value indicates an inverse relationship. For example, more years of contact sports played predicted a lower academic achievement score (*B* = -0.08). *Denotes a component significantly predicted by athletic history.

CUMULATIVE YEARS OF CONTACT SPORTS EXPOSURE EFFECTS

To examine if the number of years playing contact sports could predict the scores of the 12 gait and academic achievement measures, 12 linear regressions were performed. Among these variables, the number of years playing contact sports was a significant predictor of the academic achievement component score ($F(1, 22) = 5.05, p = 0.035, R^2 = .19$), accounting for 19% of the variance. The results indicated that individuals with more years of playing contact sports were predicted to have lower academic achievement ($B = -0.08, p = 0.035$). Years playing contact sports did not significantly predict any other variable component scores ($p > 0.05$) (Table 6).

To further examine which specific academic achievement measures could be predicted by years playing contact sports, six linear regressions were conducted. The results indicated that years playing contact sports was a significant predictor for overall undergraduate GPA ($F(1, 22) = 9.22, p = 0.006, R^2 = .29$), accounting for 29% of the variance of a participant's overall undergraduate GPA. Specifically, individuals with more years playing contact sports were predicted to have lower overall undergraduate GPAs ($B = -0.03, p = 0.006$). All other academic achievement measures were not

significantly predicted by years playing contact sports ($p > 0.05$) (Table 7).

DISCUSSION

RELATIONSHIP BETWEEN CONCUSSION HISTORY AND DUAL-TASK COST

Interestingly, results indicated that, among the limited convenience sample, participants without a history of concussion were predicted to also have greater DTC when performing a recall task while walking backward. However, descriptive statistics revealed that most participants lacked formal concussion education. Therefore, given that reported data was subjective in nature, it is possible that participants' true concussion history is inaccurate due to recall bias. Further, nine participants in the present study indicated they may have experienced more concussions than they reported in the past. A systematic review found that high-school and collegiate athletes may not report potential SRC due to underestimating injury severity, being unaware of the occurrence, and/or not wanting to be removed from athletic play.²¹ While this study did not include aspects of reporting behaviors, it may be plausible that participants without a documented concussion history harbor

Table 7. Years played contact sports predicting academic achievement component scores.

Academic Achievement Component Variables	F	R ²	B	SE	p-value
Undergraduate Science GPA	0.95	.04	-0.01	0.01	0.340
Undergraduate Program GPA	1.82	.07	-0.01	0.01	0.191
Overall Undergraduate GPA	9.22	.29	-0.03	0.01	0.006*
GRE Score	0.03	.00	-0.05	0.28	0.873
Current Graduate Program GPA	0.00	.00	0.00	0.01	0.984

Abbreviations: GPA, grade point average; GRE, graduate record examination. *Denotes an academic achievement component significantly predicted by athletic history.

unrecognized or unreported past concussions, possibly influenced by inadequate education.

RELATIONSHIP BETWEEN CONCUSSION EDUCATION AND DUAL-TASK COST

Moreover, having no concussion education significantly predicted an increased DTC when walking backward and specifically performing a visuospatial task (i.e., texting) compared to counterparts with prior education. Other researchers found that among 20 young adults aged 18-30 years without concussion, a significant DTC was experienced when participants subtracted backward (serial 6s and serial 7s; $F(4,75) = 4.21, p < 0.001$), spelled one-to-two syllable and five letter words backward ($F(4,76) = 7.68, p < 0.001$), and performed the Visual Stroop task ($F(4,76) = 8.46, p < 0.001$) while simultaneously performing various gait tasks.³³ Therefore, it is possible that participants in this study may have experienced increased DTC simply due to the nature of the dual-task activities themselves. In contrast, a separate study found that older adults with PCS experienced a significantly slower forward gait speed compared to otherwise healthy counterparts when performing the Visual Stroop task.²⁷ Additionally, it has been found that adolescent athletes with chronic SRC (>28 days) inconsistently experienced increased DTC for parameters of gait when performing a visuospatial activity similar to this study's texting task.¹³ Adolescent football players with history of repeated sub-concussive head injuries have also demonstrated chronic impairments in oculomotor testing failing to return to pre-season baseline.³⁴ Given that oculomotor dysfunction has been one of the most observed neurological deficits following repeated head injuries,³⁵ participants with unreported, unknown, and/or unrehabilitated SRC could continue demonstrating visuospatial deficits critical for clinical competency. Important to note, all the grammar and spell-check features were disabled on the mobile device used by participants in the present study. Such alterations to features typically used with today's smartphones may have contributed to increased spelling errors, irrespective of single- or dual-task paradigms, concussion history, and/or proper concussion education. It's possible that committing errors on the visuospatial texting task was mainly a factor of participants performing the task in an unforeseen/atypical way. Supporting this, research shows that students using automated corrective feedback over a 14-week period demonstrated fewer spelling errors than peers without such tools.³⁶ These findings suggest that the

acute removal of assistive technology may negatively impact spelling performance. It is not surprising that adding backward gait, which is not typical in everyday student life, may have further contributed to low performance on this specific task.

RELATIONSHIP BETWEEN ATHLETIC HISTORY AND ACADEMIC ACHIEVEMENT

Finally, among this small sample of DPT students, more years spent playing sports significantly predicted having a lower undergraduate GPA. The most recent studies exploring the effects of sport participation on academic achievement disagree with results from this study. A 2021 systematic review suggests that sport participation and academic performance are positively associated among adolescents.³⁷ A recent longitudinal study tracking participants from middle childhood to undergraduate enrollment also found that continued sport participation was positively associated with academic achievement.³⁸ Among those participants, attention and working memory, higher standardized test scores, and higher university enrollment rates were associated with longer athletic history.³⁸ Sport participation is also associated with achieving higher grades among university-aged students.³⁹ Therefore, it is entirely possible that unmitigated confounding variables could have influenced the relationship between athletic history and academic achievement reported in this study. Plausible factors such as rigorous undergraduate major(s), work-life balance, mental health, demanding schedules, and/or additional extracurricular commitments may have added to overall undergraduate GPA irrespective of athletic history.

LIMITATIONS

Participants constituted a convenience sample of already-enrolled graduate healthcare students without utility of a formal power analysis, limiting generalizability. For all linear regressions where statistical significance was not achieved ($p > 0.05$), the corresponding effect sizes were small or just at the threshold of medium in magnitude ($R^2 < 0.13$).⁴⁰ A post hoc power analysis was conducted in G*Power⁴¹ to evaluate whether the study was adequately powered at the conventional level of $1-\beta = .80$ for simple linear regressions. The results indicated that the sample was underpowered to detect a small effect ($1-\beta = .12$) or even a borderline medium effect size ($1-\beta = .58$), suggesting that limited statistical power due to sample size was a

methodological limitation of the study. A follow-up study would benefit from an a priori analysis to mitigate this limitation moving forward. Additionally, intake data was mostly subjective, as many participants relied only on memory for responses. Therefore, the true nature of concussion history or severity among the study's subjects is not entirely clear. Furthermore, other confounding variables, such as potential mental health conditions (e.g., Adult Attention-Deficit/Hyperactivity Disorder), were not controlled for. Participants were tasked with performing a total of 33 trials, often with moderate waiting periods as other participants cycled through stations, which may have simultaneously introduced fatigue as well as a learning effect. Although all 33 trials were inherently different regarding modalities and the tasks themselves, participants may have become more comfortable and efficient with testing protocols over time.

CONCLUSIONS

Graduate healthcare students receive education and training regarding safe management of patients; however, data does not exist exploring potential effects of concussion history on their academic success and clinical capabilities. Results from this study offer a potential adjunct to further improving how graduate healthcare students with athletic

history are progressed in their programs. Interestingly, having no concussion history was a significant predictor for experiencing greater DTC when walking backward. However, it was found that most participants lacked proper concussion education, which also significantly predicted increased DTC (texting while walking backward). Finally, without controlling for plausible confounding variables, participants with longer athletic history were predicted to have achieved a lower undergraduate GPA, but not GRE score or current GPA.

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CONFLICTS OF INTEREST

The authors report no conflicts of interest.

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REFERENCES

1. Report to Congress on traumatic brain injury in the United States: epidemiology and rehabilitation. Accessed January 29, 2025. <https://stacks.cdc.gov/view/cdc/29215>
2. Macauley K, Laprino S, Brudvig T. Perceptions of physical therapy students on their psychomotor examinations: a qualitative study. *Med Sci Educ.* 2022;32(2):349-360. doi:[10.1007/s40670-022-01514-z](https://doi.org/10.1007/s40670-022-01514-z)
3. Harmon KG, Clugston JR, Dec K, et al. American Medical Society for Sports Medicine position statement on concussion in sport. *Br J Sports Med.* 2019;53(4):213-225. doi:[10.1136/bjsports-2018-100338](https://doi.org/10.1136/bjsports-2018-100338)
4. O'Neill JA, Cox MK, Clay OJ, et al. A review of the literature on pediatric concussions and return-to-learn (RTL): Implications for RTL policy, research, and practice. *Rehabil Psychol.* 2017;62(3):300-323. doi:[10.1037/rep0000155](https://doi.org/10.1037/rep0000155)
5. Federation of State Boards of Physical Therapy. NPTE Pass Rate Reports. FSBPT. 2025. Accessed May 7, 2025. <https://www.fsbpt.org/Free-Resources/NPTE-Pass-Rate-Reports/NPTE-Exam-Year-Reports>
6. Lennon MJ, Brooker H, Creese B, et al. Lifetime traumatic brain injury and cognitive domain deficits in late life: the PROTECT-TBI cohort study. *J Neurotrauma.* 2023;40(13-14):1423-1435. doi:[10.1089/neu.2022.0360](https://doi.org/10.1089/neu.2022.0360)
7. Eliason PH, Galarneau JM, Kolstad AT, et al. Prevention strategies and modifiable risk factors for sport-related concussions and head impacts: a systematic review and meta-analysis. *Br J Sports Med.* 2023;57(12):749-761. doi:[10.1136/bjsports-2022-106656](https://doi.org/10.1136/bjsports-2022-106656)
8. Grants L, Powell B, Gessel C, Hiser F, Hassen A. Gait under dual-task conditions in the concussed adolescent and young athlete population: a systemic review. *Int J Sports Phys Ther.* 2017;12(7):1011-1022. doi:[10.26603/ijsp20171011](https://doi.org/10.26603/ijsp20171011). PMID:29234553
9. Kleiner M, Wong L, Dubé A, Wnuk K, Hunter SW, Graham LJ. Dual-task assessment protocols in concussion assessment: a systematic literature review. *J Orthop Sports Phys Ther.* 2018;48(2):87-103. doi:[10.2519/jospt.2018.7432](https://doi.org/10.2519/jospt.2018.7432)
10. Patricios JS, Schneider KJ, Dvorak J, et al. Consensus statement on concussion in sport: the 6th International Conference on Concussion in Sport–Amsterdam, October 2022. *Br J Sports Med.* 2023;57(11):695-711. doi:[10.1136/bjsports-2023-106898](https://doi.org/10.1136/bjsports-2023-106898)
11. Medicine BPGL and BA of S and E. Sport Concussion Office Assessment Tool 6 (SCOAT6). *Br J Sports Med.* 2023;57(11):651-667. doi:[10.1136/bjsports-2023-106859](https://doi.org/10.1136/bjsports-2023-106859)
12. Mitchell KM, Cinelli ME. Balance control in youth hockey players with and without a history of concussions during a lower limb reaching task. *Clin Biomech.* 2019;67:142-147. doi:[10.1016/j.clinbiomech.2019.05.006](https://doi.org/10.1016/j.clinbiomech.2019.05.006)
13. Lowe L, Castillo F, Allen M, Israel M, Yates C. Spatiotemporal parameters of gait among adolescent athletes with concussion when performing a visuospatial cognitive task. *Int J Sports Phys Ther.* 2023;18(2):338-347. doi:[10.26603/001c.71361](https://doi.org/10.26603/001c.71361)
14. Howell DR, Buckley TA, Berkstresser B, Wang F, Meehan WP. Identification of post-concussion dual-task gait abnormalities using normative reference values. *J Appl Biomech.* 2019;35(4):290-296. doi:[10.1123/jab.2018-0454](https://doi.org/10.1123/jab.2018-0454)
15. Bevilacqua ZW, Kerby ME, Fletcher D, et al. Preliminary evidence-based recommendations for return to learn: a novel pilot study tracking concussed college students. *Concussion.* 2019;4(2):CNC63. doi:[10.2217/cnc-2019-0004](https://doi.org/10.2217/cnc-2019-0004)
16. McAvoy K, Eagan-Johnson B, Dymacek R, Hooper S, McCart M, Tyler J. Establishing consensus for essential elements in returning to learn following a concussion. *J Sch Health.* 2020;90(11):849-858. doi:[10.1111/josh.12949](https://doi.org/10.1111/josh.12949)
17. Lowry R, Haarbauer-Krupa JK, Breiding MJ, Thigpen S, Rasberry CN, Lee SM. Concussion and academic impairment among U.S. high school students. *Am J Prev Med.* 2019;57(6):733-740. doi:[10.1016/j.amepre.2019.08.016](https://doi.org/10.1016/j.amepre.2019.08.016)
18. Renga V. Clinical evaluation and treatment of patients with postconcussion syndrome. *Neurol Res Int.* 2021;2021(1):5567695. doi:[10.1155/2021/5567695](https://doi.org/10.1155/2021/5567695)
19. McInnes K, Friesen CL, MacKenzie DE, Westwood DA, Boe SG. Mild traumatic brain injury (mTBI) and chronic cognitive impairment: a scoping review. *PloS One.* 2017;12(4):e0174847. doi:[10.1371/journal.pone.0174847](https://doi.org/10.1371/journal.pone.0174847)

20. Hallock H, Mantwill M, Vajkoczy P, et al. Sport-related concussion. *Neurol Clin Pract*. 2023;13(2):e200123. doi:[10.1212/CPJ.000000000000200123](https://doi.org/10.1212/CPJ.000000000000200123)
21. Craig DI, Lininger MR, Vomacka MM, Tiscareno R. Concussion reporting behaviors of athletes: a systematic review. *Athl Train Sports Health Care J Pract Clin*. 2020;12(2):81-88. doi:[10.3928/19425864-20190322-01](https://doi.org/10.3928/19425864-20190322-01)
22. Lynall RC, Zukowski LA, Plummer P, Mihalik JP. Reliability and validity of the protokinetics movement analysis software in measuring center of pressure during walking. *Gait Posture*. 2017;52:308-311. doi:[10.1016/j.gaitpost.2016.12.023](https://doi.org/10.1016/j.gaitpost.2016.12.023)
23. Vallabhajosula S, Humphrey SK, Cook AJ, Freund JE. Concurrent validity of the zeno walkway for measuring spatiotemporal gait parameters in older adults. *J Geriatr Phys Ther*. 2019;42(3):E42-E50. doi:[10.1519/JPT.0000000000000168](https://doi.org/10.1519/JPT.0000000000000168)
24. Newman G. How to Assess Mental Status - Neurologic Disorders. Merck Manual Professional Edition. August 2023. Accessed May 7, 2025. <https://www.merckmanuals.com/professional/neurologic-disorders/neurologic-examination/how-to-assess-mental-status>
25. Mitchell CJ, Cronin J. Methodological critique of concussive and non-concussive dual task walking assessments: a scoping review. *Int J Environ Res Public Health*. 2023;20(6):5227. doi:[10.3390/ijerph20065227](https://doi.org/10.3390/ijerph20065227)
26. Howell DR, Osternig LR, Chou LS. Adolescents demonstrate greater gait balance control deficits after concussion than young adults. *Am J Sports Med*. 2015;43(3):625-632. doi:[10.1177/0363546514560994](https://doi.org/10.1177/0363546514560994)
27. Kestens K, Degeest S, Miatton M, Keppler H. An Auditory Stroop Test to implement in cognitive hearing sciences: development and normative data. *Int J Psychol Res*. 2021;14(2):37-51. doi:[10.21500/20112084.5118](https://doi.org/10.21500/20112084.5118)
28. Howell DR, Seehusen CN, Wingerson MJ, Wilson JC, Lynall RC, Lugade V. Reliability and minimal detectable change for a smartphone-based motor-cognitive assessment: implications for concussion management. *J Appl Biomech*. 2021;37(4):380-387. doi:[10.1123/jab.2020-0391](https://doi.org/10.1123/jab.2020-0391)
29. Howell DR, Stillman A, Buckley TA, Berkstresser B, Wang F, Meehan WP. The utility of instrumented dual-task gait and tablet-based neurocognitive measurements after concussion. *J Sci Med Sport*. 2018;21(4):358-362. doi:[10.1016/j.jsams.2017.08.004](https://doi.org/10.1016/j.jsams.2017.08.004)
30. Lowe LM, Gokun Y, Williams DK, Yates C. Spatiotemporal parameters of adolescent gait when performing a visuospatial memory task. *Int J Sports Phys Ther*. 2019;14(5):753-760. doi:[10.26603/ijsp20190753](https://doi.org/10.26603/ijsp20190753)
31. Martini DN, Sabin MJ, DePesa SA, et al. The chronic effects of concussion on gait. *Arch Phys Med Rehabil*. 2011;92(4):585-589. doi:[10.1016/j.apmr.2010.11.029](https://doi.org/10.1016/j.apmr.2010.11.029)
32. Hahs-Vaughn DL, Lomax R. *An Introduction to Statistical Concepts*. 3rd ed. Routledge; 2012.
33. Robertson D, Lempke LB, Lynall RC. Analyzing dual-task paradigms to improve postconcussion assessment and management. *J Sport Rehabil*. 2024;33(5):356-364. doi:[10.1123/jsr.2023-0292](https://doi.org/10.1123/jsr.2023-0292)
34. Zuidema TR, Bazarian JJ, Kercher KA, et al. Longitudinal associations of clinical and biochemical head injury biomarkers with head impact exposure in adolescent football players. *JAMA Netw Open*. 2023;6(5):e2316601. doi:[10.1001/jamanetworkopen.2023.16601](https://doi.org/10.1001/jamanetworkopen.2023.16601)
35. Stephen SJ, Hasman L, Goldenberg M, et al. Short-term neurologic manifestations of repetitive head impacts among athletes: A Scoping Review. *J Head Trauma Rehabil*. 2022;37(5):318-325. doi:[10.1097/HTR.0000000000000767](https://doi.org/10.1097/HTR.0000000000000767)
36. Sanosi AB. The impact of automated written corrective feedback on EFL learner's academic writing accuracy. *J Teach Engl Specif Acad Purp*. 2022;(0):301-317. doi:[10.22190/JTESAP2202301S](https://doi.org/10.22190/JTESAP2202301S)
37. Owen KB, Foley BC, Wilhite K, Booker B, Lonsdale C, Reece LJ. Sport participation and academic performance in children and adolescents: a systematic review and meta-analysis. *Med Sci Sports Exerc*. 2022;54(2):299-306. doi:[10.1249/MSS.0000000000002786](https://doi.org/10.1249/MSS.0000000000002786)
38. Owen KB, Foley BC, Smith BJ, et al. Sport participation for academic success: evidence from the longitudinal study of Australian children. *J Phys Act Health*. 2023;21(3):238-246. doi:[10.1123/jpah.2023-0506](https://doi.org/10.1123/jpah.2023-0506)
39. Muñoz-Bullón F, Sanchez-Bueno MJ, Vos-Saz A. The influence of sports participation on academic performance among students in higher education. *Sport Manag Rev*. 2017;20(4):365-378. doi:[10.1016/j.smr.2016.10.006](https://doi.org/10.1016/j.smr.2016.10.006)
40. Aberson C. *Applied Power Analysis for the Behavioral Sciences: Second Edition*. Routledge; 2019.

41. Faul F, Erdfelder E, Buchner A, Lang AG. Statistical power analyses using G*Power 3.1: tests for correlation and regression analyses. *Behav Res Methods*. 2009;41(4):1149-1160. doi:[10.3758/BRM.41.4.1149](https://doi.org/10.3758/BRM.41.4.1149)

SUPPLEMENTARY MATERIALS

Appendix A

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